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As a response to the 'Mathematics Problem' many universities introduced mathematics support provision. These additional learning opportunities were invariably in a specific physical location and available at certain times. In order to increase the number and types of students who could access support e-learning resources were made available using the internet. Recent technological developments with handheld devices, notably the Apple video iPod have presented new opportunities to allow mathematics support to become mobile. This paper describes the evolution from real to virtual and now mobile support provided through two key initiatives: mathcentre and mathtutor.

1 INTRODUCTION

During the 1990s much attention was given to the 'Mathematics Problem' (see for example, LMS, IMA and RSS (1995) and Hawkes and Savage (2000)). The Mathematics Problem had many aspects but one that caused concern to universities was the changing nature of incoming undergraduate students (Lawson (1997) and Lawson (2003)), particularly to courses such as engineering where mathematics is not the main subject of study (Sutherland and Pozzi, 1995).

One response to this aspect of the Mathematics Problem that was made by many universities was the introduction of mathematics support: that is, the provision of learning opportunities in addition to the standard provision of lectures, tutorials and problems classes. A survey carried out in 2000 (Lawson, Halpin and Croft, 2003) revealed that almost half of UK higher education institutions had some form of mathematics provision. A more recent survey (Perkin and Croft, 2004) has found that since the original survey several more HEIs have started to provide mathematics support.

In this paper we will describe how mathematics support has progressed over the last fifteen years from an activity that had a fixed physical location, limited time availability and was heavily dependent on human resource, through the provision of e-support using the internet to its latest manifestation offering m-learning resources. This is not to suggest that one type of support has replaced another. Rather, the increasingly diverse range of learners that are now found in higher education makes it necessary to provide a range of mechanisms in order to provide effective support for as many students as possible.

2 MATHEMATICS SUPPORT CENTRES

One of the first mathematics support centres in UK universities was the BP Mathematics Centre at Coventry University established in 1991. The nature of the support offered here has been replicated and adapted at many other institutions. The BP Mathematics Centre offered students a range of learning resources, mainly paper-based, covering mathematical topics at the interface between school and university mathematics. The key element of the support was personal, one-to-one contact with a tutor. The support at Coventry has always operated on a drop-in basis with students able to come into the centre at a time convenient to them and engage in personal discussion about their mathematical difficulties with a tutor. Other universities adopted a different model by requiring students to make appointments in advance with tutors. There are advantages and disadvantages with either arrangement and it is beyond the scope of this paper to discuss these.

The value of such support centres has been established through statistical analysis of the performance of centre users compared with similar students who make no use of the centre at all (Hunt, Tabor and Whitehead (1995) and Lee, Harrison, Pell and Robinson (2006)). Student feedback has also been obtained through questionnaires and email comments. This feedback is typically very positive. Two typical examples (one from Coventry University and one from Loughborough University) are given below.

> *I'd just like to comment on what an excellent facility I found the Maths Support Centre to be. The assistance provided was always excellent. The printed handouts are very useful too.*

> *I just wanted to say a big thank you to you and all the staff in the maths learning support centre. I have always found the centre staff ready to help and think it is a fantastic asset to the university.*

A third measure of the value of support centres is the amount that students use them. During the academic year 2005/6, the Mathematics Support Centre at Coventry University (as it was renamed when funding from BP was no longer forthcoming) received 2889 student visits. That the number of visits is so high indicates that students value the support they receive from the centre.

The range of resources offered by support centres has expanded since the early 1990s. Newer resources such as videos and computer assisted learning materials have been made available in some centres. However, surveys amongst users (Lawson *et al*, 2003) reveal that it is the one-to-one interaction with tutors that is most highly valued by students. The non-human resources that are most popular with students are short (typically two sides) paper-based handouts.

3 ON-LINE SUPPORT

As internet technology advanced and universities moved more into e-learning it was not surprising that mathematics support should also be provided on-line (Lawson, Reed and Tyrrell, 2002). Certain groups of students such as part-timers and mature students with family responsibilities sometimes find it difficult to access the physical support centre because their time on campus is limited. The provision of internet-based resources enables such students to access support.

Many institutions developed their own on-line provision. However, it was realised that, just as had occurred with the development of paper-based resources in support centres, there was the likelihood of much duplication of effort if each university developed its own on-line mathematics support.

The LTSN (Learning and Teaching Support Network) Generic Centre therefore provided funding to develop a pilot virtual support centre initially called the United Kingdom Mathematics Learning Support Centre, now known more succinctly as 'mathcentre' (http://www.mathcentre.ac.uk). This web-site provides a collection of resources including short leaflets, longer teach yourself booklets and interactive exercises. The site is structured so that students can indicate their discipline and then be presented with resources that are appropriate (for example, business studies students do not need resources on trigonometry). Alternatively students can simply use the site's search tool from the outset and enter the topic on which they wish to work and they will then be presented with a complete list of all the resources on this topic that are held in mathcentre's database.

The site can be used by staff as well as students. Staff can, of course, access all the resources that students can. However, they have two additional facilities. Firstly, they can download handouts in bundles. So, for example, if someone wishes to establish a physical support centre at their own institution and requires handouts on a range of topics to be available in their centre, they can download a bundle of handouts in one go (whereas students have to download resources one at a time). The second additional facility is a collection of teaching resources such as the MathsTEAM booklets (MathsTEAM, 2003a, 2003b, 2003c).

The value of the mathcentre web-site is demonstrated by unsolicited emails of praise that are received by the site (such as the two shown below) and the volume of usage of the site as measured in the number of hits it receives (shown in Figure 1 below).

> *I'd just like to thank you for providing such a service. I am currently studying SL Mathematics for the IB Diploma at The British School of Warsaw, Poland and I find your resources a brilliant tool to supplement what I learn in class.*

> *I stumbled across the site not long ago, and am I glad that I did! I am currently approaching my AS exams and this website is absolutely brilliant. This has to be one of the top maths sites available - THANK YOU!!!*

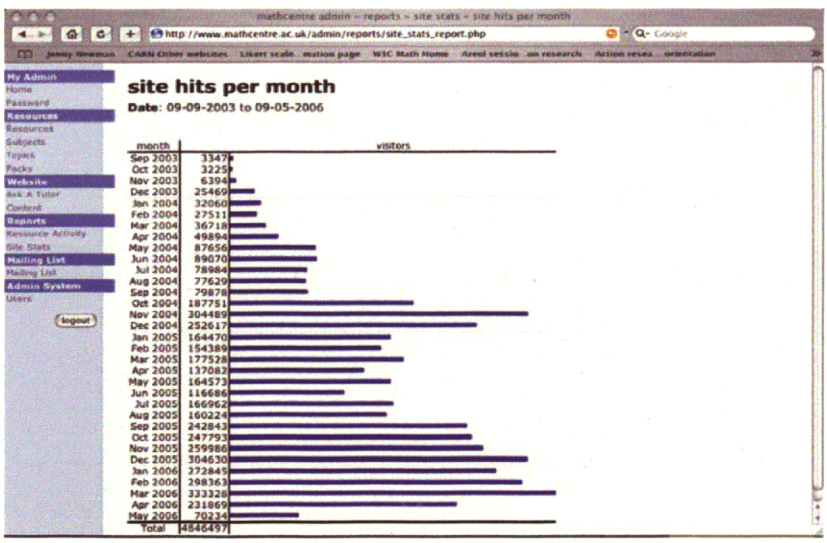

Figure 1 Number of hits per month on the mathcentre web-site

Although the site was available in September 2003, at this time it contained very few resources. During the academic year 2003/4 the volume of resources was increased significantly. In October 2004 there was a promotional campaign to inform students of the existence of the site and in the early stages of their university careers many students did access the site (with a peak of over 300,000 hits in November 2004). However, this high level of usage was not sustained and the number of hits dropped as the academic year progressed to around 175,000 hits per month. Usage in 2005/6 has been significantly higher with around 250,000 hits each full month (April contained the Easter vacation) and sustained throughout the year, with a peak of one third of a million hits in March.

4 INTEGRATED VIDEO AND E-RESOURCES

Whilst the usage statistics indicate that mathcentre is a very worthwhile resource, it was recognised that it does not provide the interaction with a tutor that students regard as the most popular resource in physical support centres. The FDTL (Fund for the Development of Teaching and Learning) project mathtutor sought to address this deficiency. The resources of mathtutor are based around a video tutorial in which a teacher introduces a mathematical topic, explains the underlying theory and carries out a number of worked examples.

Linked to the video tutorial are a range of resources:

- diagnostic exercises that allow students to self-assess their knowledge in the topic under consideration
- text resources that can be printed by the student and used as notes on the topic – the texts follow the video tutorial in terms of order the material is presented and the worked examples provided
- interactive exercises that allow students to practise the skills and concepts that have been taught in the video tutorial
- extension materials which provide a context or application of the topic (only available for some topics)
- animations which graphically illustrate the material, for example, the proof of Pythagoras theorem and the addition of two sine waves (only available for some topics)

Figure 2 shows the user interface when a video tutorial has been selected. It is not necessary to watch the whole of the video tutorial – the menu on the left of the screen allows the user to jump in to a point part way through if they are happy with the early material. The links to the other resources are under the video part of the screen.

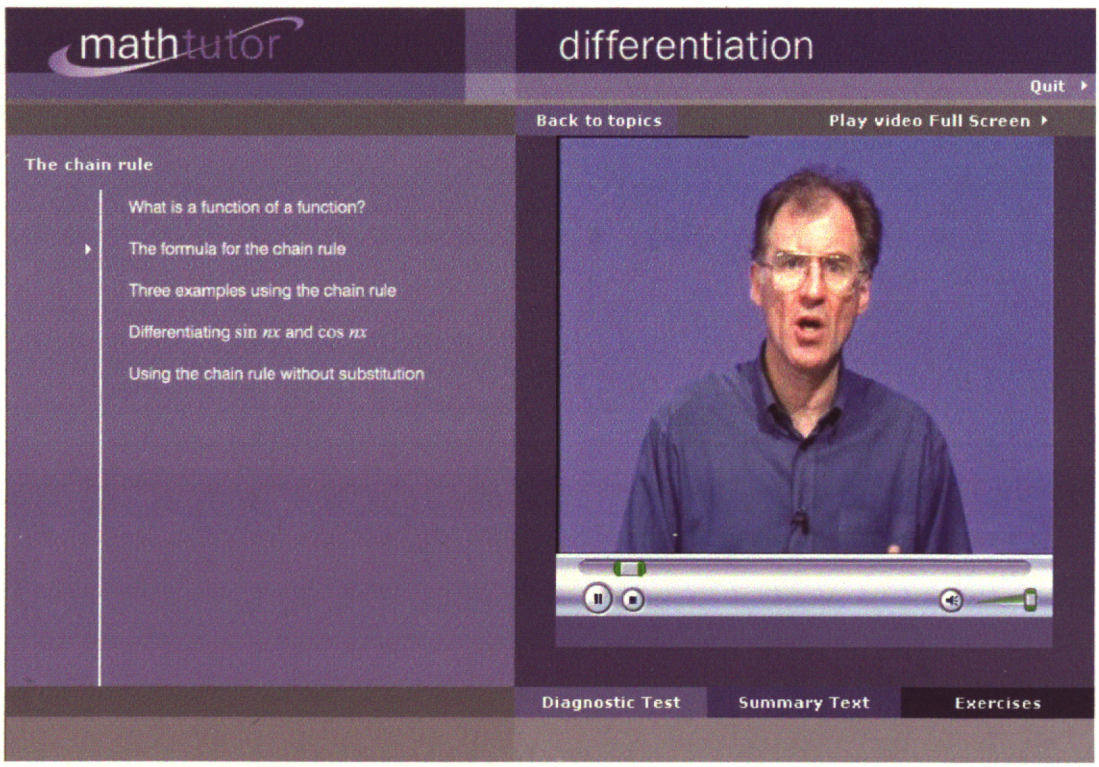

Figure 2 A screenshot of mathtutor with a video playing

These resources were initially provided on seven DVD-ROMs. However, advances in technology have enabled the integrated, easily navigable resources to be provided over the internet as well (http://www.mathtutor.ac.uk).

During the development of the materials an evaluation of student reaction to them was carried out (Gibbon, 2004). The conclusion of this evaluation was "Overall the resource was very well received by nearly everyone who looked at it and it is thought to be a very good, worthwhile resource with 85% of those responding wanting to see more".

Further evaluation has taken place at a number of universities (Gardiner, 2005) and this has again been positive. The comment below from a student email about the video tutorials is typical.

> *I'm a student at Rutgers University in New Jersey. I'm currently in Calc II and my professor (I'm not calling any names) is horrible as a teacher.*
>
> *I can't tell you how much you've helped me tremendously. Every time I visit the site and see your face I know I'll be ok. You go slow and you explain everything. You're the best.*

5 GOING MOBILE

Lee and Chan (2006) suggest that "the rise in popularity of portable electronic devices…are [sic] helping to fuel the transition from e-learning to m-learning". Their work goes on to extol the benefits of podcasting in delivering m-learning. Clark and Walsh (2004) argue that portable digital audio technologies have significant potential since listening "frees eyes and hands", enabling learners to use m-learning materials in "dead time" such as walking home, waiting for a bus or whilst carrying out routine household chores.

The case for using iPods in learning is further strengthened because of their status amongst young people. Stephens (2005) claims that "no other consumer electronic device has created such an impact on popular culture in recent years as the Apple iPod".

Abram (2006) points out that a key attraction of iPods is that they "align with students' natural behaviours" in contrast to other resources that require students to "align their behaviours with uncomfortable technologies". He further asserts that "to ignore iPods and their kin in the education space in 2006 is the same as ignoring the web in 1996 or the internet in 1986".

At the start of 2006 *eLearn* asked a number of e-learning experts for their predictions for 2006 (Neal, 2006). One prediction was that "podcasting is poised to be its [m-learning's] first real widespread practical application".

In October 2005 Apple launched the video iPod. The potential of this device was quickly realised. The Times Educational Supplement (2005) reported on "the new podagogy" of 'vodcasting' (video on demand). Medical educators have been amongst the first to take advantage of this new technology with video resources being made available to health students in the community (Walton, Childs and Blenkinsopp, 2005), dental students (Diverse, 2006a) and healthcare professionals (Diverse, 2006b).

The visual nature of mathematics means that audio podcasting has only limited appeal in mathematics support. However, the ability to deliver video to mobile handheld devices such as the Apple iPod presents a significant opportunity for mathematics support. This will enable mathematics resources to move from e-learning to m-learning.

As part of the mathtutor project over 80 hours of mathematics teaching video material had been produced. This material is ripe for use with this new technology. Although the conversion process is not entirely straightforward (Lawson, Carpenter, Croft and Saunders, 2006) this has been carried out and iPod versions of mathtutor videos and animations are available from

http://www.mathtutor.ac.uk/ipod.shtml and
http://learn.lboro.ac.uk/nmsc/iPod/iPod.html.

However, further consideration needs to be given to the nature of mathematics support resources that are provided for m-learning of this kind. Lee (2005), Lee and Chan (2006) and Walsh (2004) suggest that resources for m-learning need to be short (approximately 5 to 10 minute duration). As Tynan (2006) puts it "It's [video iPod] great for watching 4-minute music videos. But when I want to view a 43-minute show, I'd rather do it on my couch."

To respond to this need for shorter resources, the mathtutor videos (which typically are around 45 minutes in length) are being made available in sections (that mirror the different entry points to the videos when viewing them on a PC from a disk or over the internet – as seen in the left half of the screenshot in Figure 2). By downloading these sections in the correct order into an iPod playlist the whole video can be watched seamlessly if so desired. In addition, a number of shorter excerpts each featuring just a single worked example are also being made available.

6 CONCLUSIONS

Mathematics support was originally founded on personal interaction with a tutor. This is a costly method of support and for financial reasons it is necessary to supplement this mode with other resources. Furthermore, some learners may find it difficult to access drop-in support – this is particularly true of part-time students who may not be available during the support centre opening hours and of mature students with family responsibilities who can only spend limited time on campus. The provision of e-resources can help to address the needs of some of these learners. Internet-based resources do not have the restrictions of time and place that a physical support centre has. However, these resources do still require a PC and

notwithstanding the growth in laptop ownership and wireless provision this still represents a limitation. New technology such as the video iPod enables mathematics support to be available in a much more mobile way. Resource development for mobile mathematics support is still in its infancy – but the potential is undeniable.

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BIOGRAPHICAL NOTES

Duncan Lawson is Director of the Coventry branch of SIGMA – Centre for Excellence in Mathematics and Statistics Support, a HEFCE Centre for Excellence in Teaching and Learning (CETL). Duncan has been Director of the Mathematics Support Centre at Coventry University since 1994 and has been involved in national projects such as mathwise, mathcentre and mathtutor. In 2005 he was award a National Teaching Fellowship by the Higher Education Academy.

Sarah Carpenter, at the time of writing this paper, was Assistant Director of SIGMA, working across both the Coventry and Loughborough sites. Before joining SIGMA, Sarah worked for the Higher Education Academy Engineering Subject Centre (formerly LTSN Engineering) at Loughborough University. Sarah has now moved to be the e-learning Change Champion for Cardiff University.

Tony Croft is Director of the Loughborough branch of SIGMA. Tony joined Loughborough University to establish the Mathematics Learning Support Centre and he is now Director of the Mathematics Education Centre. He has been involved in national projects such as mathcentre and mathtutor and has authored a wide range of textbooks on mathematics for engineers and other non-specialist mathematicians.